DISTRIBUTED DOMAIN GENERATION BASED ON THE NETWORK ENVIRONMENT CHARACTERISTICS FOR DYNAMIC AD-HOC NETWORKS

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ABSTRACT

Ad hoc networks are very important for scenarios where there is not fixed network infrastructure. These scenarios may appear both in the military and the commercial world. Even though there is much advancement in the area of these networks, the main drawback is that ad hoc networks do not scale well because the existing protocols (e.g., MAC, routing, security) cannot tolerate their dynamics. A remedy to this problem could exist if these protocols were applied in hierarchical manner. The hierarchy generation in these dynamic environments can be advantageous since the numerous topological changes can be tolerated easier and the various protocols can perform better when dealing with smaller groups of nodes. On the other hand, hierarchy has to be generated carefully in order to be beneficial for the network otherwise it may harm it, because of the imposed maintenance overhead. The weakness of the existing network clustering algorithms is that they do not take into consideration the dynamics of the network environment, so in cases of increased mobility their overhead may deteriorate network performance instead of improving it. In this paper we present a new dynamic distributed clustering (DDC) algorithm. The basic characteristic of this algorithm is that it takes into consideration the network dynamics for the generation of robust and efficient clusters. DDC can be applied in highly mobile networks and we show that it presents better scalability and robustness characteristics from well known existing clustering algorithms.

1. INTRODUCTION

The utilization of Mobile Ad Hoc Networks (MANETs) as part of future military systems (i.e., FCS) is required but is a challenging task. The requirement is justified from the scenarios that may appear in the battlefield where most of the times there is no pre-existing infrastructure for communications, so this infrastructure must be generated dynamically. The challenge to develop these networks in a level where they can be used as part of the military systems arises from their dynamic characteristics. A critical requirement imposed to the design of these networks is to scale for many thousands of nodes. The accomplishment of the latter objective is not a trivial task because of the dynamic nature of these networks - the various protocols (routing, security, QoS) fail to capture the network dynamics for large number of nodes. Many studies exist where new improved protocols are proposed for MANETs but their main disadvantage is their inability to scale to large number of nodes. The solution that has been proposed to remedy the scalability problem is to generate a hierarchy of domains (clusters) and apply the proposed protocols per domain. In that fashion each instance of the protocol will operate on a smaller subgroup of nodes and as a consequence it can capture its dynamics. Apart from scalability, the existence of hierarchy enhances also the robustness of the network, reduces the control overhead and the communication information, favors the spatial reuse and in general improves the performance of the network.

Having identified the benefits of hierarchy, we have to introduce efficient and sophisticated ways to generate and maintain it. The generation and maintenance of the hierarchy imposes extra overhead on the network and in order for the hierarchy to be beneficial we have to reduce this overhead. The existing work does not take into consideration the network environment but mostly focuses on the selection of clusterheads. In dynamic environments this approach may be harmful to the network performance instead of improving it because the extra overhead may offset the performance improvement. The novelty in our approach is that we take into consideration the network environment characteristics such as the mobility characteristics of the nodes (speed, direction) and the lifetime of the links (link expiration time) so that we can generate hierarchy and reduce or eliminate the overhead from the membership changes. In this work we propose a new Dynamic Distributed Clustering (DDC) scheme which unlike the existing ones treats the participating nodes equally and does not discriminate between clusterhead and non-clusterhead nodes. Also does not limit itself to the generation of domains with specific diameter (e.g., many of the existing algorithms generate domains with two hops diameter) and

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last but not least the generation of hierarchy is based on metrics related to the network environment.

2. DYNAMICC DISTRIBUTED CLUSTERING ALGORITHM (DDC)

The main objective of the DDC algorithm is to group together nodes that present similar mobility characteristics, so that the generated clusters are robust to topology changes. DDC is based on 1-hop information exchange. The information is related to the mobility characteristics of the nodes (speed, direction). The algorithm has 3 distinct phases:

Phase I – Neighbor Selection: In this phase each node broadcasts its ID and its metric value to its 1-hop neighbors. The metric can be related to the velocity, the direction or the position of the node. All the nodes collect from their 1-hop neighbors these values and based on these values they select the neighbor that best matches the clustering objectives (group together nodes with similar mobility characteristics).

Phase II – *InfoExchange* List Composition: After the nodes have decided on which is the most appropriate neighbor to form a cluster with, they inform the selected node for this decision. The recipient nodes collect the related messages and record the IDs of the nodes who have selected them. After the completion of this process, each of the nodes generates the *InfoExchange* list. The *InfoExchange* list is sorted in ascending order with respect to the node IDs.

Phase III – Cluster Formation: In this phase the nodes communicate based on the *InfoExchange* list from Phase II, in order to decide on a cluster. Each node communicates only with the nodes in its *InfoExchange* list in order to decide on the cluster that matches better its mobility characteristics, with respect to the metric of interest. The communication synchronization among the nodes is based on the node IDs (e.g., for that reason the *InfoExchange* list is sorted). Each node selects a cluster to join and transmits this decision after all nodes with lower IDs in its *InfoExchange* list have decided and transmitted their clustering decisions.

3. PERFORMANCE EVALUATION

We compared the robustness of DDC with the well known *lower ID* algorithm [1]. The performance metric of interest is the average number of membership changes. We applied both DDC and lower ID algorithms in network environments of various sizes and mobility levels. Namely, we generated networks of 100 to 1000 nodes and we applied the Random Walk model (e.g., Random Waypoint model with pause time equal to 0). We varied the maximum allowable node speed between 1m/s and 10m/s to test the ability of DDC to generate robust clusters even in scenarios of high mobility.

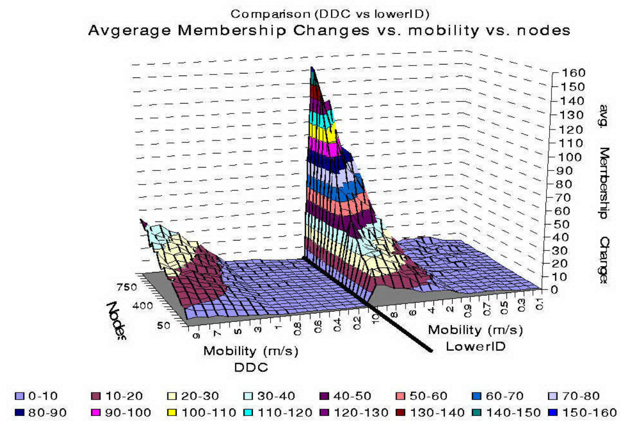

Fig. 1: Average membership changes required from lower ID and DDC algorithms

The right part of the graph represents the average membership changes of the lower ID algorithm and the left part represents the average membership changes of the DDC algorithm. The higher the mobility and the larger the size of the network, the better the performance of the DDC algorithm compared to the lower ID algorithm, with respect to the average membership changes. For 1000 nodes and 10m/s maximum speed, DDC requires on average 12000 less membership changes than lower ID algorithm.

CONCLUSIONS

The proposed algorithm (DDC) generates clusters by taking into consideration the dynamics of the network environment. The latter results in much more stable clusters compared to an algorithm that generates clusters by taking into consideration characteristics (ID of the nodes) that do not correlate with the network dynamics. Since DDC attempts to cluster together nodes with similar mobility characteristics, the robustness effect is amplified when we evaluate the algorithm with respect to a group mobility model (Reference Point Group Mobility) instead of the Random Waypoint model. The nodes will be moving as groups and due to the clustering objectives of DDC the generated clusters will attempt to match these mobility groups, so the generated clusters will be even more robust.

REFERENCES

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